



137 CS Desorption within an estuary: modelling and experiments

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^{137}Cs DESORPTION WITHIN AN ESTUARY: MODELLING AND EXPERIMENTS

O. Radakovitch, A. Delaval, C. Duffa, I. Pairaud, P. Boyer, L. Flipo, F. Coppin,

IRSN, Institute for radioprotection and nuclear safety

IFREMER, Institut Français pour la recherche et exploitation de la mer, France

ADICT solutions, France





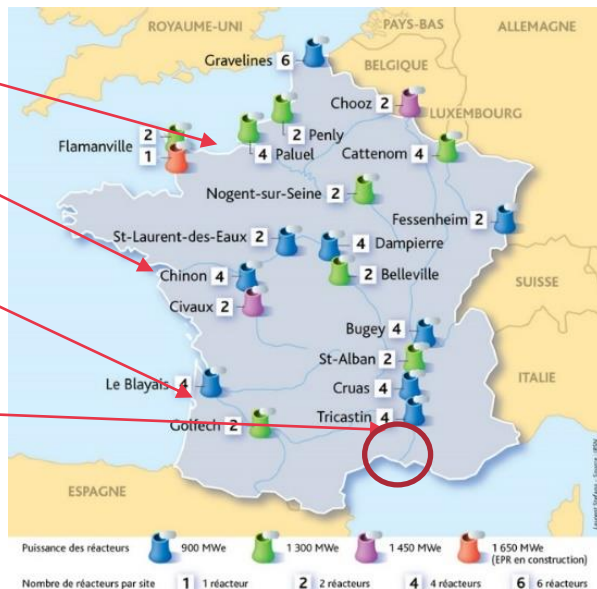
Estuaries are hot spot areas for the transfer of radionuclides

Seine 380 m³/s

Loire 825 m³/s

Garonne 545 m³/s

Rhône, 1700 m³/s



- 13 nuclear plants installed in France along four rivers.
- Scenario of accidental releases of radionuclides must take into account the coastal areas.
- Estuaries are hot spot areas where specific physico-chemical processes (**particles cycle, salinity changes, desorption...**) may change speciation and fluxes.
- They must be correctly simulated to predict the fluxes transferred to the sea and potential impact on the ecosystems.

¹³⁷Cs

Emitted in most accidental scenarios

Half-life: 30 years

Gamma emitter → internal and external irradiation

Bioaccumulation within the trophic chain

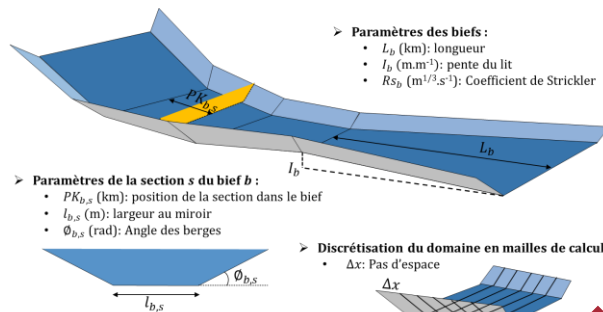


IRSN Numerical models for radionuclide transfers in aquatic systems

CASTEAUR: 1D numerical model for radionuclides transfer in rivers

Inputs:

- Hydrographic parameters
- Chronics of :
 - water and suspended particles
 - Radionuclides releases (various inputs)
 - Sediments and radionuclides properties



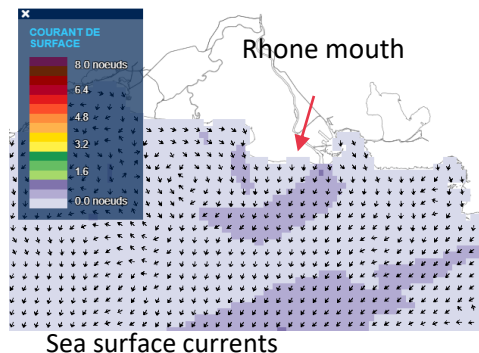
Outputs:

- Water flow, water height, ...
- Suspended particulate matter content and sediment deposition.
- Dissolved and particulate Radionuclides concentrations and fluxes in water column and sediments**

STERNE: 3D numerical model for radionuclides dispersion in the ocean

Inputs:

- Hydrodynamic data from oceanographic model (SHOM)
- Chronics of :
 - Radionuclides by direct releases or atmospheric deposition
 - Chemical and radioecological parameters (FC, Tp, Tb_{1/2}...)



Outputs:

Radionuclides concentrations in water, particles and biota



Model need for the different estuaries (well mixed to salt-wedge)



DRACAR : Désorption des RAdionuCléides à l'interfAce littoRale

DRACAR

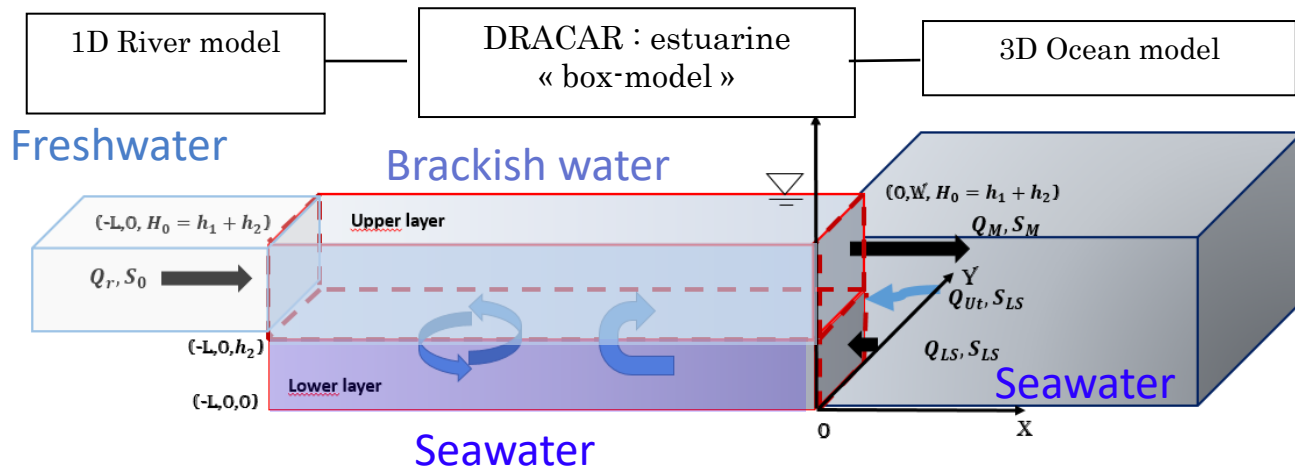
Based on

Physical outputs

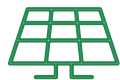
Box-model for freshwater-seawater mixing within estuary and structure of water masses.

- Solving salt, volume and potential energy budgets.
- Knudsen's theorem.

- Physical structure of the water masses
- Water residence time in the estuary
- 2D salinity
- Water and salinity fluxes at sea



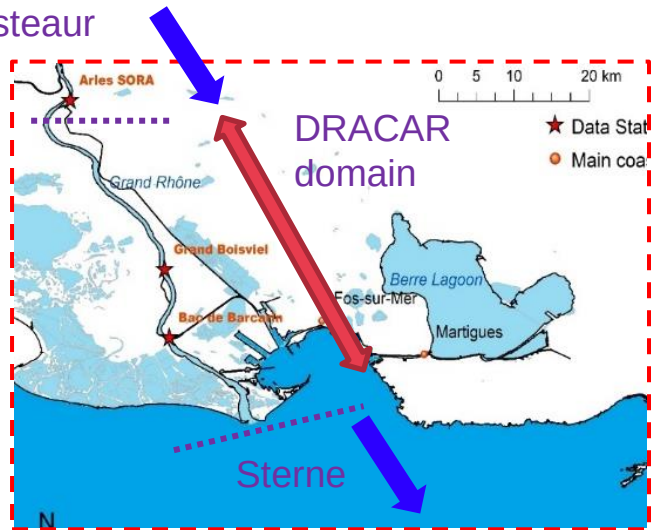
Delaval et al 2022



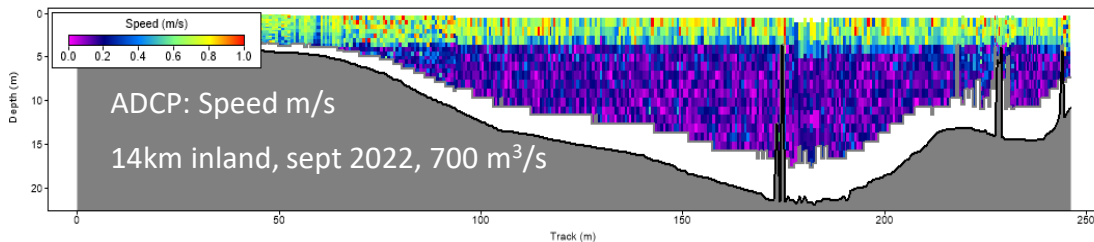
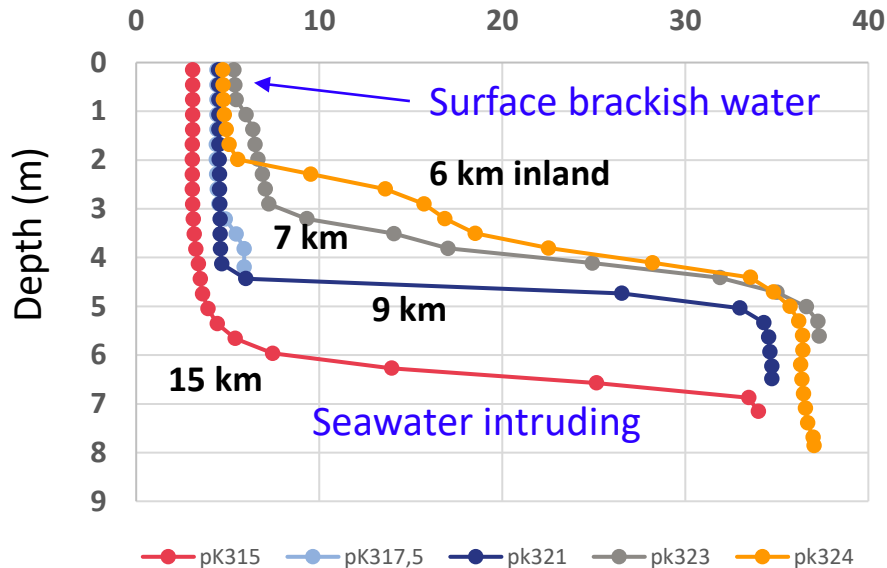
The Rhone Salt-wedge estuary

Below $1500 \text{ m}^3/\text{s}$, a salt-wedge intrudes up to 30 km, in relation with water discharge.

Casteaur



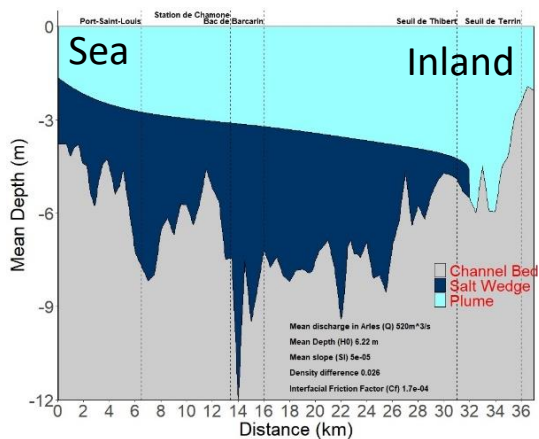
Salinity - 8th July 2022





DRACAR simulation

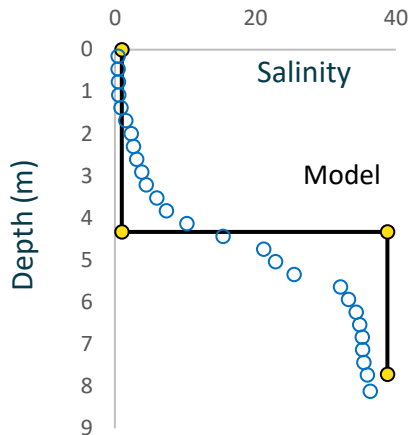
Salt-wedge structure



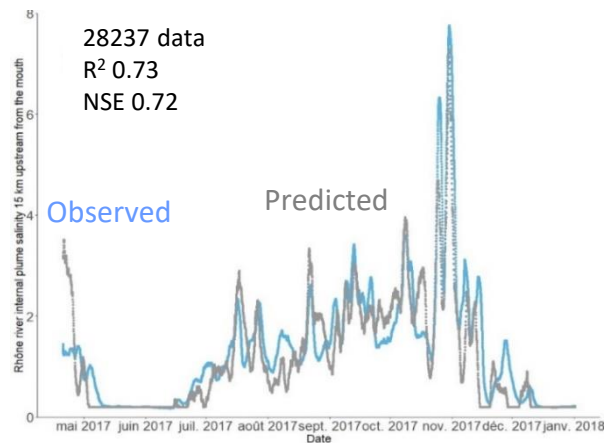
- ✓ More realistic value for river flux to the sea.
- ✓ Flushing time for particles between 0 and 37 g/L.



Salinity profile - 8 km inland

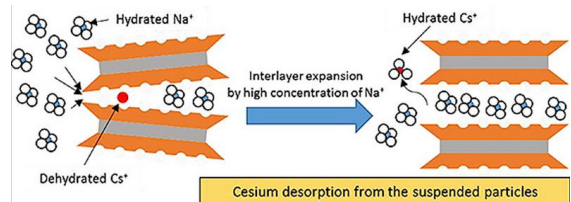


Surface salinity - 15km inland



Integration of desorption process

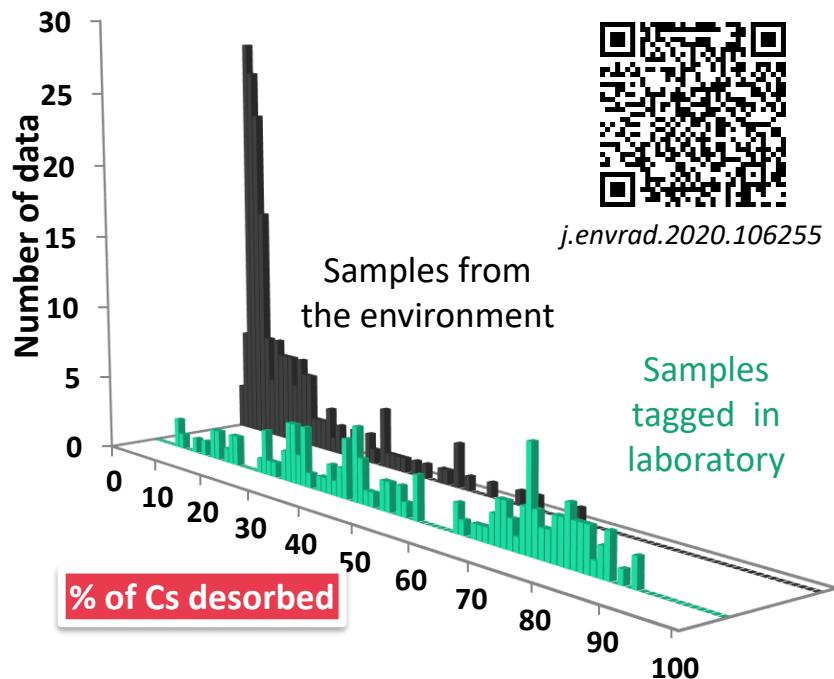
Intensity of particulate ^{137}Cs desorption due to the exchange with dissolved seawater cations (K^+ , Na^+)





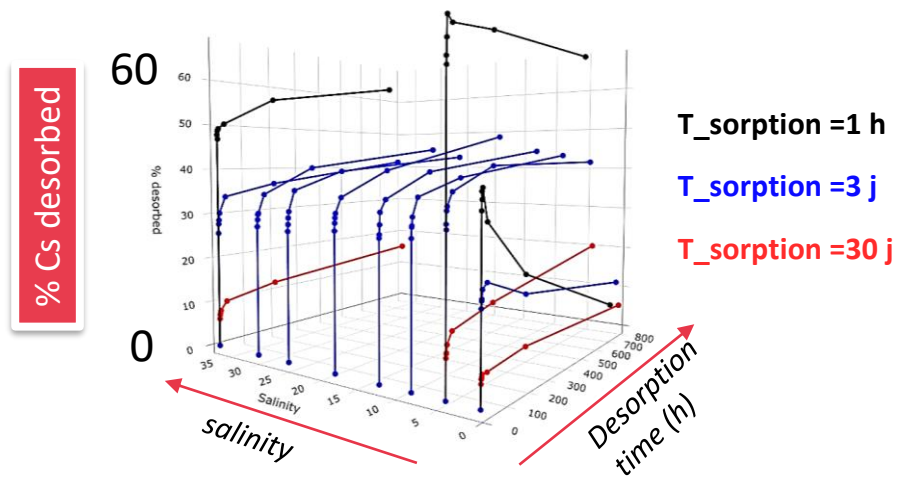
Desorption of ^{137}Cs at the fresh-seawater interface

Compilation of 32 studies from 1963 to 2017

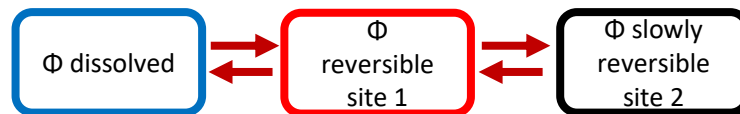


- No clear trend with salinity
- Existence of an « ageing » effect

Desorption in laboratory to test the influence of salinity and ageing effects



- Desorption initiates at 0,2-4 g/L salt
- Ageing effect influences desorption
- A two kinetics model simulates well the process





Simulation of Cs flux (Bq/s) along the continuum

Release of dissolved ^{137}Cs

Rhône flood

$Q = 2300 \text{ m}^3/\text{s}$
 $\text{SPM} = 1 \text{ g/L}$



Dissolved 
Reversible site 
Slowly reversible 

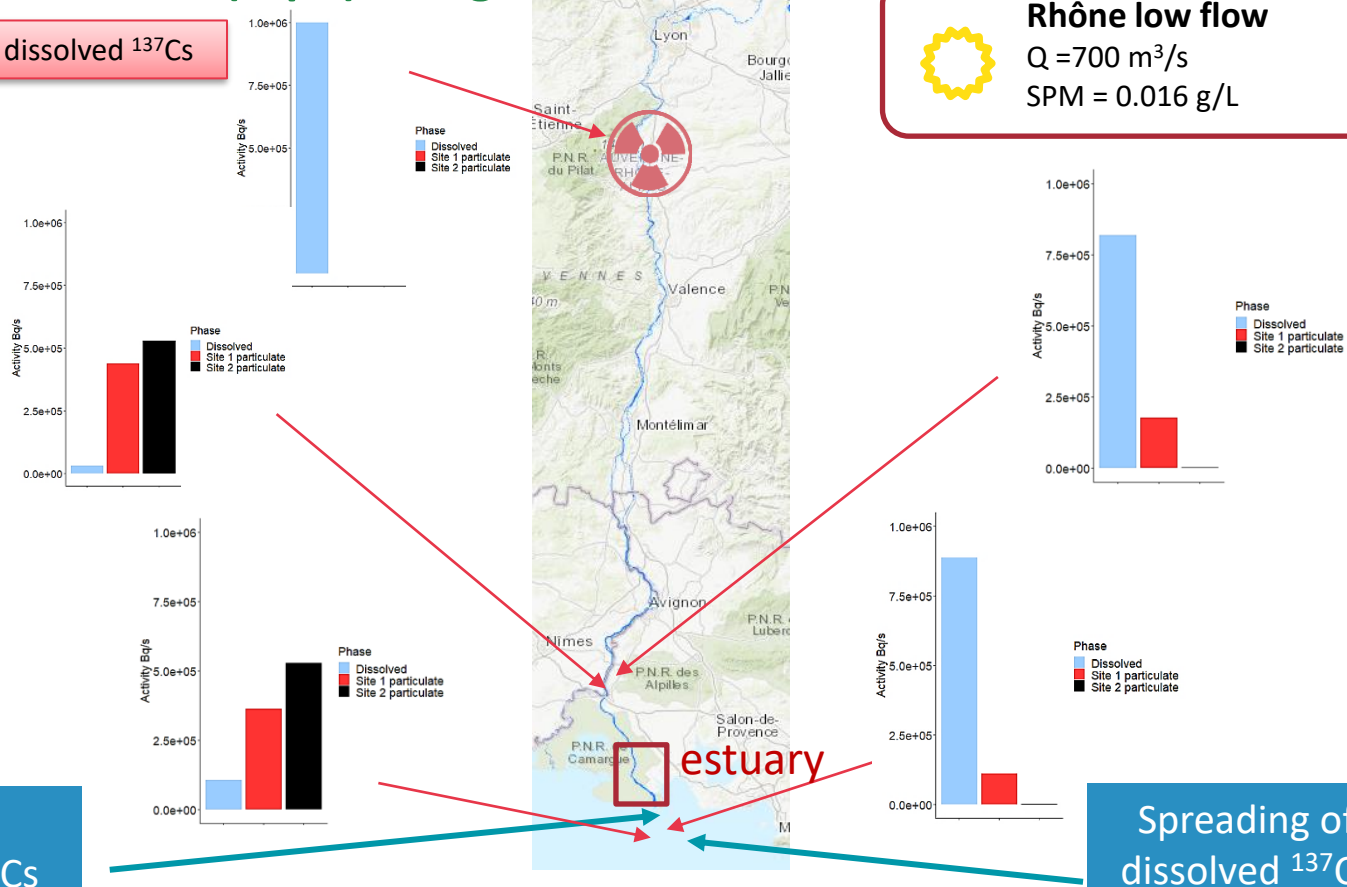
Settling of
particulate ^{137}Cs

Rhône low flow

$Q = 700 \text{ m}^3/\text{s}$
 $\text{SPM} = 0.016 \text{ g/L}$



Spreading of
dissolved ^{137}Cs

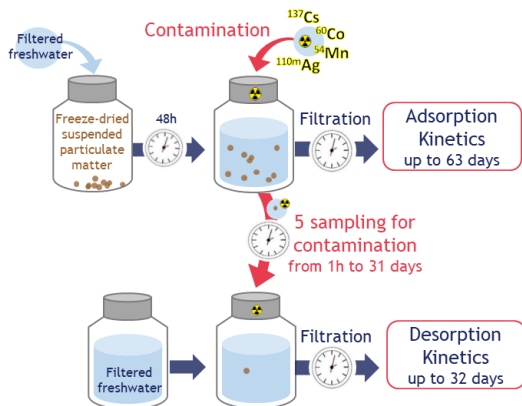
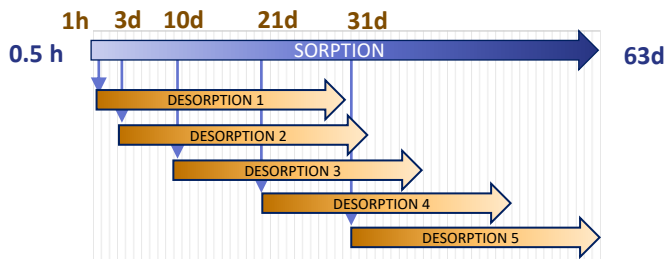




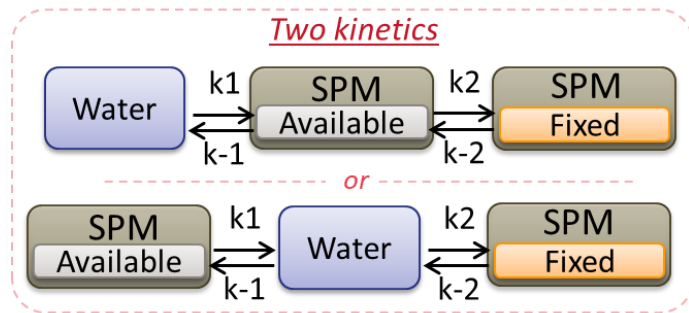
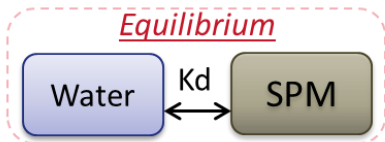
Adsorption-desorption experiments for Cs, Co, Mn and Ag

- ^{137}Cs $^{110\text{m}}\text{Ag}$ ^{60}Co ^{54}Mn onto Rhone suspended particulate matter
- Desorption after 30 min to 2 months**

- Define which sorption-desorption model is most suited to described changes in the river continuum (transit time, chemical changes...)

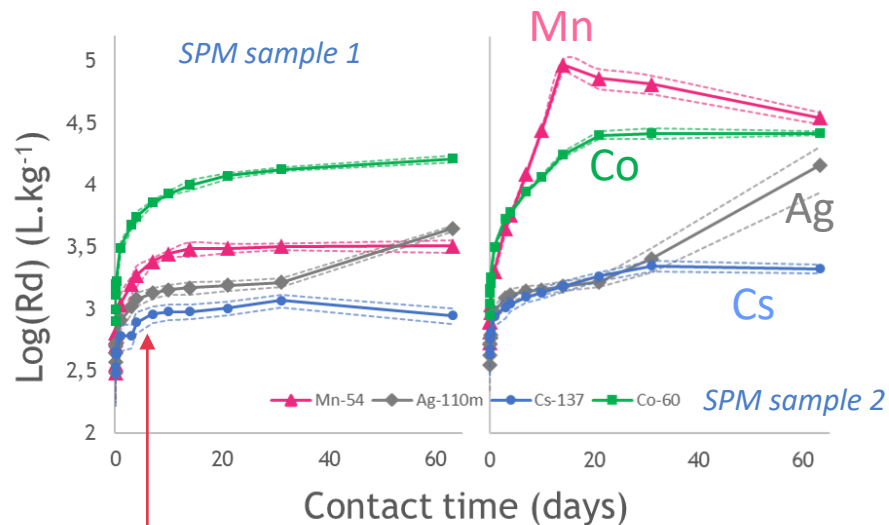


dataset

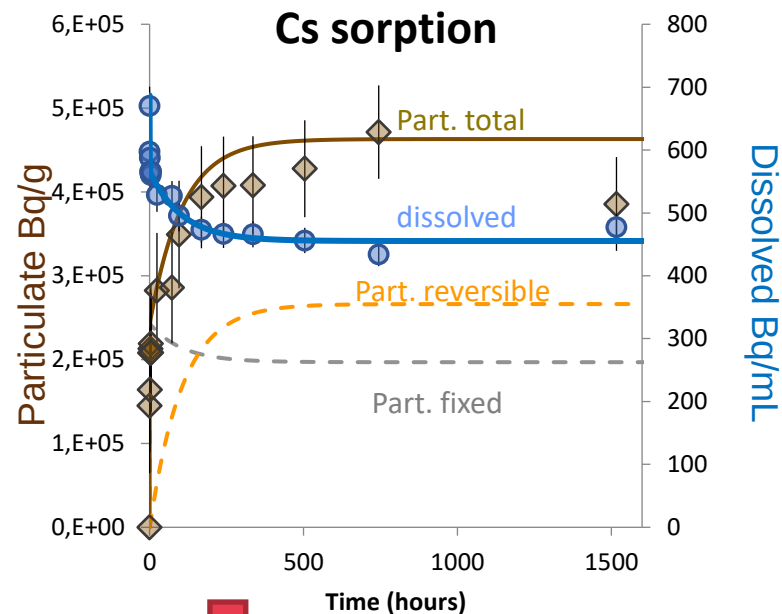


First results of the experiment

Solid/dissolved activities



Transit time in the Rhone from nuclear plant locations to the sea is less than 6 days.



Conclusions

- The hydrodynamic of the water masses are well represented for a salt-wedge estuary, as well as water and salt budgets.
- The desorption of ^{137}Cs occurs very quickly (2 g/L) in brackishwater
- The duration of adsorption have an influence on the ^{137}Cs desorption, still difficult to constrain.
- Geochemical models including sorption – desorption kinetics are more realistic, but parameters are difficult to acquire.